Section III. REMARKS

Objections to Claims 39-41, and Response Thereto

In the February 12, 2003 Office Action, the Examiner objected to claims 39-41 for reciting "said AlGaN spacer layer" that lacks antecedent basis.

In response, Applicants have hereby amended claims 39-41, and such claims as amended overcome the Examiner's objections.

Rejection of Claims on Reference Grounds, and Traversal Thereof

In the February 12, 2003 Office Action, the Examiner rejected claims 1-9 and 35-42 on various reference grounds. Specifically, the Examiner rejected:

Claims 1-4, 7-8, 35-38, and 42 under 35 U.S.C. 103(a) as being obvious over **Hiroharu** Japanese Patent Application Publication No. JP-09307097 (hereinafter "Hiroharu") in view of **Streit** et al. U.S. Patent No. 5,668,387 (hereinafter "Streit");

Claims 5-6, 39, and 40-41 under 35 U.S.C. 103(a) as being obvious over **Hiroharu** in view of **Streit** and further in view of **Schetzina** U.S. Patent No. 5,670,798 (hereinafter "Schetzina"); and

Claim 9 under 35 U.S.C. 103(a) as being obvious over **Hiroharu** in view of **Streit** and further in view of **Pao** et al. U.S. Patent No. 5,270,798 (hereinafter "Pao").

In response, Applicants have herein amended claims 1-3, 5-9, 35, and 39-42.

Applicants respectfully traverse the Examiner's rejections of the pending claims 1-9 and 35-42 as amended, based on the following patentable distinctions between the claimed invention and the cited references.

Claim 1 of the present application as amended, from which all the remaining claims 2-9 and 35-42 depend, recites:

> "**A gallium nitride-based HEMT device**, comprising **a channel layer comprising an InGaN alloy and at least one additional layer over said**

channel layer, wherein said at least one additional layer comprises **material selected from the group consisting of AlGaN, GaN, and InGaN**, with **the proviso that when said at least one additional layer comprises AlGaN material, said AlGaN material is $Al_xGa_{1-x}N$, wherein x is less than 0.2**."

As stated on page 3, lines 11-24 of the instant specification, although the conventional AlGaN/GaN HEMT structures have demonstrated promising output powers, the device performance of such AlGaN/GaN HEMTs is limited by persistent photoconductivity (PPC) and drain I-V collapse, which are caused by defect-donor complexes (DX centers) formed in **high Al content AlGaN layers**, which are defined compositionally as **$Al_xGa_{1-x}N$, where $x>0.20$**, and which are commonly used to achieve high sheet densities via piezoelectric-induced doping in the AlGaN/GaN HEMT structures.

The present invention provides a novel and inventive solution for the above-described problem associated with the conventional AlGaN/GaN HEMT structures, by **forming an InGaN channel layer on the GaN buffer layer, which permits employment of** "**substantially lower Al composition AlGaN layers**" in the HEMT structures "**at equivalent levels of strains and piezoelectric doping characteristic** of [conventional] AlGaN/GaN heterostructures [that have high Al content AlGaN layers]" (see the instant specification, page 5, lines 18-20). As a result, it is now possible to produce "**AlGaN/InGaN heterostructures that enable the use of reduced Al content AlGaN layers without significant reductions in piezoelectric-induced doping or degradation of the structural or electrical properties of the channel layer**" (see the instant specification, page 6, lines 3-5).

Therefore, **formation of an AlGaN layer having a low or reduced aluminum content** (i.e., **an aluminum composition ratio x of less than 0.2**, which is substantially lower than that of the high Al content AlGaN layers used in the conventional AlGaN/GaN HEMT structures) **over the InGaN channel layer in the HEMT device** constitutes **an important and essential feature of Applicants' claimed invention when AlGaN is employed**.

Applicants of the present application have further discovered that **the use of such InGaN channel layer can be employed to completely eliminate the chemically reactive Al-containing layer in the HEMT device, by replacing the AlGaN layers with GaN or InGaN layers therein**.

The Hiroharu reference cited by the Examiner discloses in paragraph [0052] a HEMT having the AlGaN/InGaN structure, while the undoped InGaN layer functions as a channel layer.

However, the AlGaN layer in such HEMT disclosed by Hiroharu has a high Al content, which is consistent with the high Al content of the AlGaN layer in conventional AlGaN/GaN structures. Specifically, in paragraph [0042]-[0043], Hiroharu discloses a conventional AlGaN/GaN HEMT structure (the 2nd operation form) having an undoped GaN channel layer 12, a n-type AlGaN layer 19 over said channel layer 12, and an undoped AlGaN layer 20 over such n-type AlGaN layer 19 (see Figure 6 of Hiroharu), **wherein the aluminum composition ratio or aluminum content of both the n-type AlGaN layer 19 and the undoped AlGaN layer 20 is 0.2**, consistent with the use of high levels of aluminum in conventional AlGaN/GaN HEMT structures. (See, for example, page 4, right column, second paragraph of the article entitled "$Al_xGa_{1-x}N$/GaN High Electron Mobility Transistor (HEMT)" by Pouya Valizadeth at http://www-personal.engin.umich.edu/~ pvalizad/ganhemt.pdf visited on May 7, 2003, describing a conventional AlGaN/GaN/GaN HEMT having an aluminum content of **0.33**.)

In paragraph [0052], while describing the AlGaN/InGaN HEMT structure of the 3rd operation form, Hiroharu discloses that the AlGaN layer used in the AlGaN/InGaN HEMT structure of the 3rd operation form is the same as that used in the AlGaN/GaN HEMT structure of the 2nd operation form. It is therefore evident that the AlGaN layer used in the AlGaN/InGaN HEMT structure according to the 3rd operation form of Hiroharu also has a high aluminum content (i.e., aluminum composition ratio of 0.2).

Hiroharu did not appreciate or even contemplate the advantage of using an InGaN channel layer as a basis for forming an AlGaN layer of low Al content in a HEMT device. Instead, it continues to use the same type of high Al content AlGaN layer in the HEMT structure, even after an InGaN channel layer has been employed therein. As a result, the AlGaN/InGaN HEMT structure formed by Hiroharu continues to suffer from persistent photoconductivity (PPC) and drain I-V collapse caused by high Al content in the AlGaN layer.

Hiroharu therefore does not provide any derivative basis for forming a high quality HEMT structure having an AlGaN layer of low Al content (i.e., $x<0.20$) on an InGaN channel layer, which is expressly required by all the pending claims of the present application.

Streit does not teach or suggest in any manner about formation of a HEMT structure with an AlGaN layer of low Al content (i.e., $x<0.20$) on an InGaN channel layer, either. Therefore, Streit does not remedy the deficiency of Hiroharu.

Further, neither the Hiroharu or the Streit reference provides any derivative basis for forming a HEMT structure having an InGaN or GaN layer directly on the InGaN channel layer, as recited in pending claims of the present application.

In the February 12, 2003 Office Action, the Examiner attempted to remedy such deficiency of Hiroharu with respect to the InGaN or GaN layer formed directly on the InGaN channel layer, by citing the Schetzina reference and asserting that the teaching in Schetzina about continuously graded InGaN/InGaN layers used in multiple quantum well (MQW) can be combined with the teachings of Hiroharu reference about HEMT structures for constructing an InGaN/InGaN HEMT structure as claimed.

However, the AlGaN/GaN or AlGaN/InGaN layers disclosed by **Hiroharu** are used in **a HEMT structure**, which is characterized by **an undoped channel layer** and a highly doped donor layer (see Page 9 of the article entitled "High Speed Transistor Technologies" by Alex Huber at http://www.microswiss.ch/tld/2001/papers/transistors_technos.pdf, visited on May 7, 2003), while the continuously graded InGaN/InGaN layers disclosed by **Schetzina** are used in **a MQW structure**, which is characterized by **multiple AlGaN, InGaN and/or GaN layers that are all doped to have a certain conductivity** (see Schetzina, column 12, lines 15-16, column 13, lines 38-42 and lines 49-50, column 14, lines 32-33; see also the article entitled "Photoluminescence Microscopy of InGaN Quantum Wells" by Herzog et al., Appl. Phys. Lett., vol. 70, no. 11 (March 17, 1997), stating that "**all of the layers [in the InGaN/GaN MQW structure] were intentionally doped** *n* type with silicon).

Therefore, **the structure and composition of the HEMT devices disclosed by Hiroharu are fundamentally different from those of the MQW devices disclosed by Schetzina**, and **a person ordinarily skilled in the art would not have been motivated to use the doped InGaN layers from the MQW devices disclosed by Schetzina as the channel and donor layers in the HEMT devices disclosed by Hiroharu**, since **the doped InGaN layer in a MQW device cannot be reasonably expected to successfully perform the function of an undoped channel layer in a HEMT device**.

The Examiner's arbitrary combination of certain elements of these two entirely different devices disclosed separately by Hiroharu and Schetzina thus **derives solely from improper hindsight of the instant invention, and is not supported by any reasonable expectation of success**.

Pao does not remedy the above-described deficiency of the Hiroharu, Streit, and Schetzina references.

Therefore, claims 1-9 and 35-42 patentably distinguish over all the cited references, by requiring **a gallium nitride-based HEMT device** that has **a channel layer comprising an InGaN alloy and at least one additional layer thereover**, wherein the at least one additional layer **comprises material selected from the group consisting of AlGaN, GaN, and InGaN**, with **the proviso that when said at least one additional layer comprises AlGaN material, said AlGaN material is $Al_xGa_{1-x}N$, wherein x is less than 0.2**.

Applicants hereby respectfully request the Examiner to reconsider, and upon reconsideration to withdraw, the rejections of claims 1-9 and 35-42 as amended herein.

CONCLUSION

Claims 1-9 and 35-42 as amended herein are now in form and condition for allowance. Issue of a Notice of Allowance for the application is therefore requested.

No fee is rendered payable herein. Nevertheless, the Office is authorized charge any fee that is deemed necessary for entry of this Amendment to Deposit Account No. 08-3284 of Intellectual Property/Technology Law.

If any issues remain outstanding, incident to the formal allowance of the application, the Examiner is requested to contact the undersigned attorney at (919) 419-9350 to discuss same, in order that this application may be allowed and passed to issue at an early date.

Respectfully submitted,

Yongzhi Yang
Reg. No. (see attached)
Attorney for Applicants

Steven J. Hultquist
Reg. No. 28021
Attorney for Applicants

INTELLECTUAL PROPERTY/
TECHNOLOGY LAW
P.O. Box 14329
Research Triangle Park, NC 27709
Phone: (919) 419-9350
Fax: (919) 419-9354
Attorney File No.: 2771-410 RCE